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Title: Radiation Survey Instrumentation

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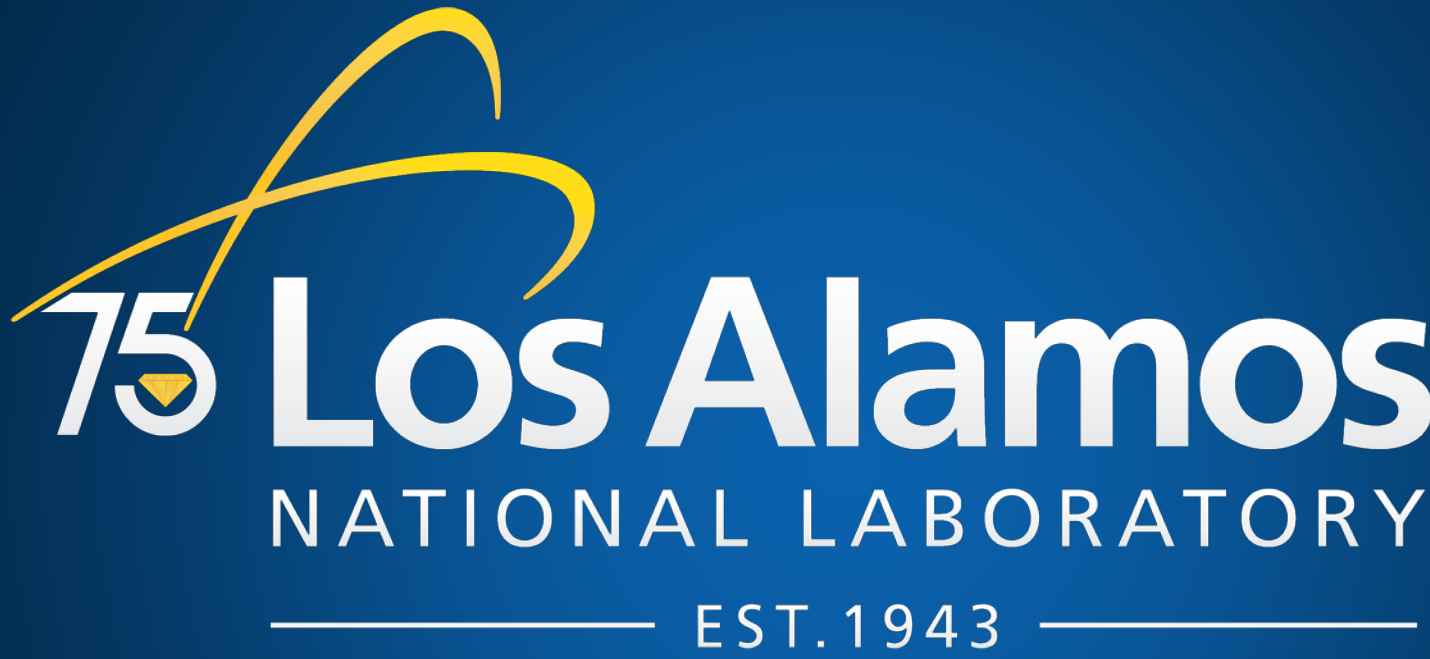

Radiation Survey Instrumentation

DOE-HDBK-1122-2009

Module 2.16

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Agenda

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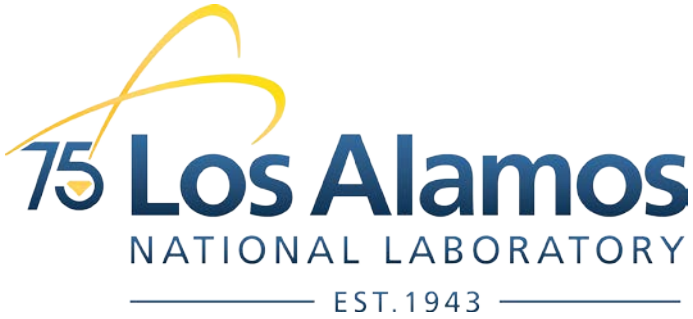


- **Objectives:**
- **2.16.01: Factors affecting instrument selection of appropriate instrument for external surveys**
- **2.16.02: Features and specifications (F&S) for ion chambers**
- **2.16.03 F&S for high-rate instruments**
- **2.16.04 F&S for neutron detection and measurement**

Introduction: class discussion

What is purpose or goal of external radiation surveys ?

What type of type of radiation fields are of interest in external surveys ?

What sort of facilities or operations would external surveys be of potential interest ?

Introduction:

- **External radiation control measurements and accurate postings are dependent on accurate measurements of external dose and exposure**

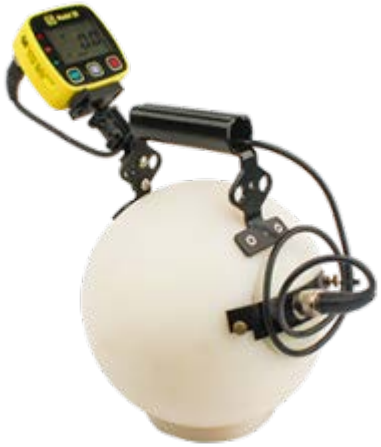
- **Reliant on the appropriate instrument for the particular survey**
  - Based on type, energy and activity of the radiation
  - Correct use and operation of the instrument (training !)
  - Calibration of the instrument in a known field approximating the conditions during the survey (how likely is this ?)
  - Conditions such as:
    - background levels
    - presence of interfering radiation
    - pulsed fields (e.g. accelerators or neutron generators)
    - environmental conditions (e.g. temperature, humidity, RF fields, magnetic fields)
  - Requirements as specified in Procedures

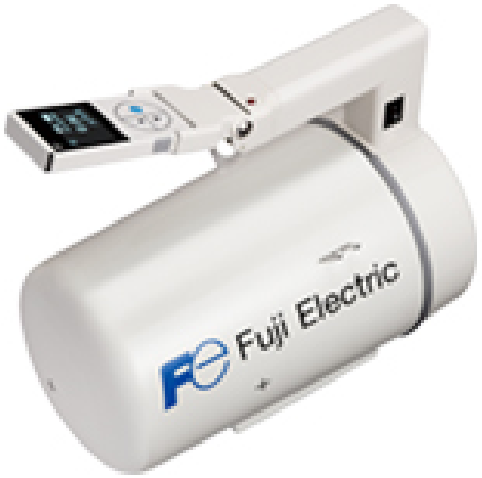
2.16.01: Instrument selection considerations

- **Quantity to be measured:**
  - For exposure measurements an ion chamber is best choice
    - Relatively flat energy response
    - Also suitable for beta absorbed dose measurements (beta shield open) but correction factor is required
    - Vented chambers suitable for fields > 1 mrem/h but also susceptible to temperature and humidity effects
    - Pressurized (sealed) ion chambers suitable for exposure levels near background levels
  - For gamma dose equivalent measurements
    - Plastic scintillators have excellent tissue equivalence (e.g. Bicron micro-rem meter)
    - Energy compensated GMs (hot dog probes)
    - NaI-based probes are highly sensitive but very poor tissue equivalency
    - Ion chambers often used as well (1R ~ 1rem)
    - In high fields (>5 R/h or rem/h), the use of teletectors (GM-based) best conforms to the principles of ALARA

2.16.01: Instrument selection considerations

- **Quantity to be measured:**
  - For neutron dose measurements a rem ball is the most common choice
    - Provides continuous coverage across wide range of neutron energies
    - Gamma insensitive
    - But heavy (>20lb) and can lead to ergonomic injuries
    - Other options exist including a lighter weight version (7” diameter as opposed to 9” diameter polyethylene sphere)





2.16.01: Pre-operational checks

- **Generally specified in the relevant instrument operating procedure. But typically includes several of the following:**
  - Check for any obvious signs of damage (dents, rattling, loose knobs, etc…)
  - Verify calibration is valid i.e. not past due
  - Check battery level indicator and change if required
  - If applicable, zero the display (e.g. ion chambers)
  - Do a source response check and compare to past checks
  - Verify location of effective center (look for markings)
    - Can be important when making contact measurements and in comparing readings taken by different instruments
  - Others ?

2.16.01: Other instrument selection criteria

- **Are beta and/or low energy gamma measurements of interest ?**
  - Consider instrument shielding (housing) and entrance window thickness
  - Consider use of an instrument with a beta shield
    - Be aware that correction factor required for beta absorbed dose measurement when instrument calibrated for gamma dose or exposure.
    - Also difficult to distinguish between betas and low energy gamma or x-ray photons.

- **Is the instrument appropriate for the task at hand?**
  - Check vendor's specs on energy range covered by instrument
  - Check vendor's specs on dose rate limits

2.16.01: Additional comments

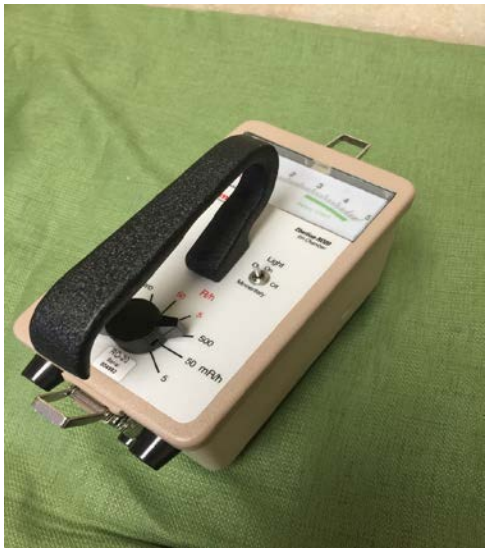
- **Instruments designed for external measurements are calibrated in terms of dose or exposure rate**
  - Readout units in terms of mrem/h, μR/h, R/h, etc ….
  - Displays can be analog or digital
    - Be aware of geotropism with analog meters
  - Displays can be auto-scaling or require user to switch manually
    - Be aware that auto-scaling may go un-noticed

- **Remember that instruments are calibrated while fully irradiated in reference field**
  - If instrument is only partially illuminated then correction factors are likely required
    - For example, an ion chamber used to measure streaming through a shield wall

2.16.02: Ion chamber instruments

- **Designed to measure exposure or air kerma (dose)**
  - A rate meter measurement is often the only operating mode option
- **Vented ion chambers use air as detector medium**
  - Readings dependent on ambient temperature and barometric pressure
- **Pressurized ion chambers for environmental-level measurements**
  - N_2 and Ar gas commonly used
  - Pressures up to 24 atm.

2.16.02: Ion chamber instruments



Vendor/Model: Thermo RO20

Type: Ion chamber

Radiation detected: Gamma and beta

Dimensions: 7.9” x 4.2” x 7.7”

Weight: 1.6 kg

Active volume: 220 cm^3

Interferences:

Energy response: Excellent

Energy range: 8keV-1.3 MeV window open, 30 keV- 1.3 MeV closed

Dose rate range: 0.1 mR/h – 50 R/h

Sensitivity: ~ 25 pA per R/h

Beta shield: Yes, 7 mg/cm^2

Response time: 10-90% within 5s

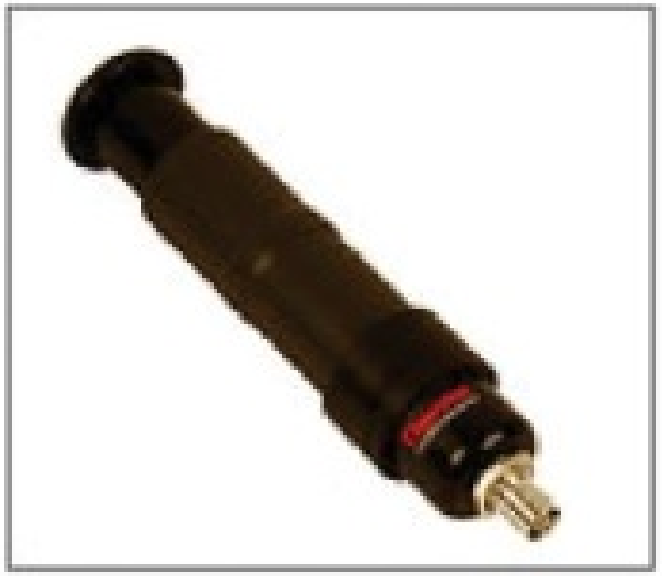
Temperature limits: -40°C to 80°C

Bias voltage: 36v

Comments:

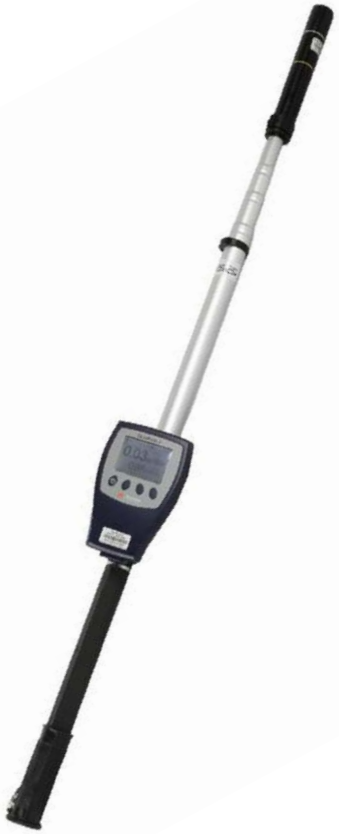
2.16.02: GM instruments

Vendor/Model: Thermo HP270
Type: Energy compensated “hot dog” GM
Radiation detected: Gamma and beta
Dimensions: 6.0” x 1.5” diameter
Weight: 0.14 kg
Active volume: 14 cm^3
Interferences:
Energy response: Good
Energy range: 30 keV- 1.3 MeV closed
Dose rate range: 0.020 mR/h – 3 R/h
Sensitivity: 1200 cpm/ (mR/h)
Beta shield: Yes, 30 mg/cm^2
Dead time: 100 µs
Temperature limits: -40^{o}C to 75^{0}C
Bias voltage: 900v
Comments: Needs rate meter



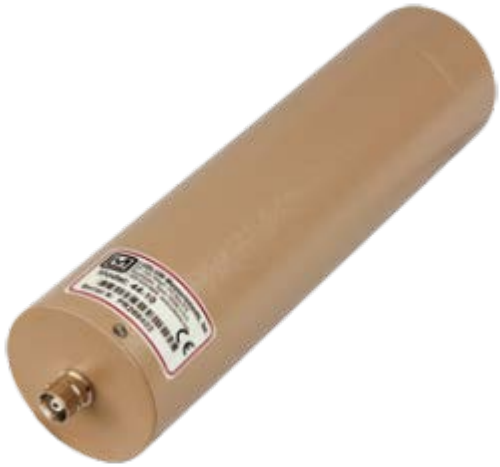
2.16.02: GM instruments

Vendor/Model: Mirion BAK-2283
Type: Energy compensated teletector GM (2)
Radiation detected: Gamma and beta
Dimensions: 11’ long when extended
Weight: 2.0 kg
Active volume: ~10 cm^3
Interferences: Beta (high-energy)
Energy response: Good (+/- 25%)
Energy range: 50 keV- 2.0 MeV
Dose rate range: 0.020 mR/h – 1.5 R/h
Sensitivity: 1080 cpm/ (mR/h)
Beta shield: No
Dead time: 50µs
Temperature limits: -20^{o}C to 50^{0}C
Bias voltage: 900v
Comments: Needs rate meter



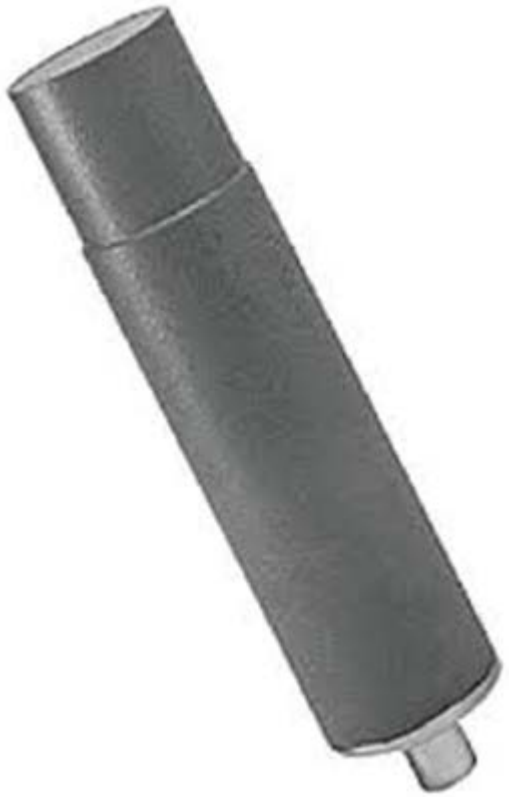
2.16.02: Scintillator instruments

Vendor/Model: Ludlum 44-10
Type: NaI(Tl) 2”x2”
Radiation detected: Gamma
Dimensions: 11.0” x 2.6” diameter
Weight: 1.04 kg
Active volume: 102 cm^3
Interferences: Beta
Energy response: Poor
Energy range: 50 keV - 3 MeV
Dose rate range: background to 3 mrem/h
Sensitivity: 900 cpm/ (µR/h)
Beta shield: No
Response time: dependent on rate meter setting
Temperature limits: -40°C to 75°C
Bias voltage: 500-2000v dependent on PMT
Comments: Needs rate meter



2.16.02: Scintillator instruments

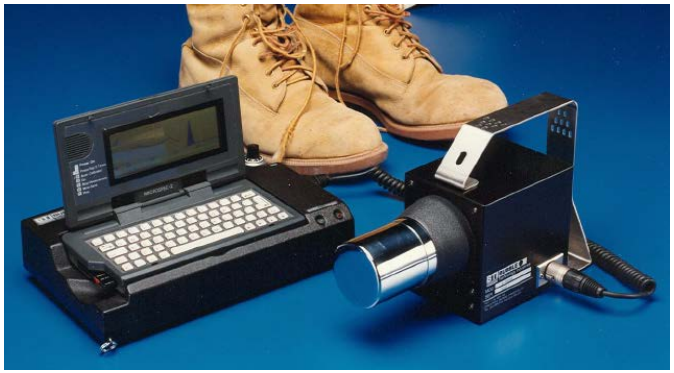
Vendor/Model: Thermo SPA3
Type: NaI(Tl) 2”x2” scintillator
Radiation detected: Gamma
Dimensions: 11.0” x 2.6” diameter
Weight: 1.5 kg
Active volume: 102 cm^3
Interferences: Beta
Energy response: Poor
Energy range: 60 keV - 3 MeV
Dose rate range: background to 3 mrem/h
Sensitivity: 1200 cpm/ (µR/h)
Beta shield: No
Response time: dependent on rate meter setting
Temperature limits: -30^{o}C to 60^{0}C
Bias voltage: 500-2000v dependent on PMT
Comments: Needs rate meter



2.16.02: Scintillator instruments

Vendor/Model: Bubble Technology Industries, Microspec-2 E probe

Type: NaI(Tl) 2”x2” scintillator



Radiation detected: Gamma

Dimensions: 6.0” x 3.6” x 10”

Weight: 1.4 kg (probe), 1.9kg (analyzer unit)

Active volume: 102 cm^2

Interferences: Beta

Energy response: Very good (spectroscopy-based)

Energy range: 60 keV - 3 MeV

Dose rate range: background to 3 mrem/h

Sensitivity: 1000 cpm/ (µR/h)

Beta shield: No

Response time: dependent on rate meter setting

Temperature limits: -30^{0}C to 60^{0}C

Bias voltage: 500-2000v dependent on PMT

Comments: Needs dedicated analyzer unit

2.16.03: Neutron instrument

Vendor/Model: Ludlum 12-4
Type: rem ball (2 atm. ^{3}He tube)
Radiation detected: Neutron
Dimensions: 9” diameter polyethylene sphere
Weight: 8.3kg (18.3 lb) with rate meter
Active volume: 1.6cm x 2.5cm tube
Interferences: none
Energy response: Fair
Energy range: $1x10^{-8}$ – 12 MeV
Dose rate range: up to 10 rem/h
Sensitivity: 100 cpm/ (mrem/h)
Beta shield: No
Response time: dependent on rate meter setting
Temperature limits: -20^{o}C to 50^{0}C
Bias voltage: 1200v
Comments: Needs rate meter

Questions ?